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To: Dr. T.S. Drolet
Program Manager, ISSP
New Business Ventures
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TRIP REPORT:
1987 CRYOGENIC ENGINEERING CONFERENCE/
INTERNATIONAL CRYOGENIC MATERIALS CONFERENCE,
ST CHARLES, ILLINOIS, JUNE 14-18, 1987

Jeffrey R. Robins

INTRODUCTION

I attended the Cryogenic Engineering Conference/International Cryogenic Materials Conference (CEC/ICMC) in St. Charles Illinois from June 14 to 18. The Fermi National Accelerator Laboratory in Batavia hosted the conference.

The Cryogenic Engineering Conference covered topics on

- closed-cycle cryogenic refrigerators
- aerospace cryogenics
- superconducting magnet technology
- compressors
- cryogenic insulation
- the Superconducting Super Collider (SSC)

The International Cryogenic Materials Conference dealt with

- new high T_c oxide superconductors
- Chevrel phase superconductors
- material properties at cryogenic temperatures
- superconductors for the SSC
- aerospace materials characterization

There were four plenary sessions:

- "New Tools for High Energy Physics: Tevatron and SSC"
  R. Schwitters (Harvard University and Fermi National Accelerator Laboratory)

- "New Superconducting Materials"
  M. Maple (University of California at San Diego)

- "Whole Body NMR Imaging Spectrometer at 10 Tesla"
  T. Budinger (University of California at Berkeley)

- "HOTOL - A Cryogenic Materials Challenge"
  S. Walmsley and J. Wilson (British Aerospace)

The conference attracted over 700 participants from 18 countries including West Germany, Peoples Republic of China, France, Japan, USSR, England and Switzerland. Most major American universities and laboratories, such as The National Bureau of Standards and Fermilab were well represented.

Equipment manufacturers staged an equipment show, CRYO-EXPO 87. This exhibition demonstrated equipment such as closed cycle refrigerators, temperature measurement devices, large and small scale liquid helium plants, cryogenic fabrication and superconducting wire and magnet technology.

A list of future meetings on cryogenics and superconductivity announced at this conference is in Appendix I. Titles of preprints of some papers from the conference that are available from me are listed in Appendix II. The conference program, abstracts and list of attendants is also available.

TOUR OF FERMILAB FACILITIES AND THE SUPERCONDUCTING SUPER COLLIDER

A tour of the Fermilab facilities offered the opportunity to see the major cryogenic equipment at the lab. This included the main liquid helium facilities and the large Collider Detector. The helium liquefier provides cooling for the superconducting magnets in the Tevatron, the 1 TeV x 1 TeV proton - antiproton collider ring, approximately 6.5 kilometers in diameter at Fermilab. About 5000 liters of liquid helium are pumped from the central liquefier into the ring each hour. The helium is pumped out under pressure into the superconducting magnets and 24-satellite 1000-watt refrigerators in small buildings on the surface around the ring. The helium returns after its trip around the ring less than 0.5° warmer.

The tour included a series of detectors in various locations around the site. These all use superconducting magnets. The most impressive of these is the main Collider Detector. This unit stands two stories high and weighs 4500 tons. At the time of the tour this unit was out of the ring for modification. It was just in the process of being cooled down to 4K before being rolled back into the path of the beam.

A major topic at the conference was the new US $6 billion particle accelerator, the Superconducting Super Collider. The SSC is planned to be a 20 TeV x 20 TeV proton - proton collider or 20 times the energy of the Tevatron at Fermilab. It will be used to look at fundamental particles and energies that mimic those found a few billionths of a second after the Big Bang. The SSC design requires 10,000 superconducting magnets 15 meters underground in a tunnel 83 kilometers in diameter. The tour of Fermilab included a detailed look at a number of these superconducting magnet sections in various stages of construction and testing.

At Fermilab the SSC magnet assemblies were being insulated and placed in vacuum jackets for low temperature testing. Most of the areas visited were working on the superinsulation used in these magnets. The magnet cryostats need low heat loads to control the refrigeration system's capital and operating expenses. They are using heavy aluminized Mylar sheets separated by fiber glass matting. They buy blankets of this with 7 to 10 layers. Around the SSC magnets are approximately 3 to 4 sets of these blankets.

The magnet assemblies are pumped down to $< 10^{-7}$ torr. Problems with the vacuum around the insulation is not observed unless the pressure exceeds 10^{-4} torr where there is a distinct break and the insulation degrades in performance rapidly. The outside layers of the insulation must touch the shield they face. There is a 80K shield and a 20K shield. Shifting of the insulation is a problem.

There was discussion of the new high temperature superconductors having an impact on the SSC magnets. The talks at the conference, including the plenary session, indicated that the researchers involved with this device felt these new ceramics (even if there existed a way to make a magnet out of them) would not be used in the SSC. The existing technology is well understood and already in the testing stage. One of the first three magnets of the 10,000 required was at Fermilab, cooled down to liquid helium temperatures, and under full power testing when I was there.

A debate is going on in the United States as to where the SSC will be located. This is not surprising since the project is expected to provide at least 4500 construction jobs as well as a permanent work force of 3000 physicists, engineers and computer technicians. At the Conference central meeting area there were large numbers of glossy brochures from various states, advocating the location of the collider in their respective areas. A total of twenty five states submitted proposals for the site, many hand delivered by state governors. A total of 43 sites have been named.

CRYOGENIC ENGINEERING/CLOSED CYCLE HELIUM REFRIGERATION

A series of sessions on small cryocoolers discussed devices similar to the Gifford McMahon (GM) closed cycle helium refrigerator being commissioned in the Science Section. A Gifford McMahon typically operates around 15K. The refrigerators operating at 4K use one additional stage of cooling, a Joule-Thomson (J-T) expansion valve. At 4K these units have 0.5 to 4 watt capacity, in contrast to our unit with 30W at 20K. The development of these GM/J-T cycle refrigerators in the 4K range is stimulated by the use of these units on Magnetic Resonance Imaging (MRI) devices in hospitals. The large

bore superconducting magnets used on MRI devices require closed cycle cooling to make them economical.

A GM/J-T cycle refrigerator uses highly compressed helium gas. It is made up of two parts. The Gifford McMahon section expands compressed helium through a series of pistons to cool the gas to approximately 16K. The Joule-Thomson part expands the gas through an orifice to get 4K. The majority of research in this area is concerned with the reliability of refrigerators operating at 4K. There are problems with contamination, blockage and wear on moving parts. Helium compression requires oil cooled compressors. A large section of the compressor unit is therefore the oil removal equipment. Frequently, glass wool is used as an oil filter. Any contamination, at levels as low as 1 ppm, can cause difficulties at these temperatures.

In addition to oil contamination, water and hydrogen also cause problems in the cold head. The hydrogen comes from cracking of the compressor oil and is difficult to remove because light material often will not filter or coalesce. These materials accumulate in the cold head and eventually block the system. Cleaning the system and keeping it clean is the key to long periods of trouble-free operation.

The most interesting paper on cryogenic refrigeration was from the Jet Propulsion Laboratory in Pasadena. They have developed a sorption refrigerator with virtually no wear-related moving parts, no oil contamination from compressors, negligible vibration and long lifetime (at least 10 years). These units are being developed for cooling in space and have low refrigerator mass. A unit delivering 1W at 14 K is about the size of a pop can. Sorption refrigeration produces cooling by compressing a gas with physical surface adsorption or chemical internal absorption powders. The compressed gas is then expanded through a Joule-Thomson valve. In the compressor portion, low pressure gas is sorbed on to solids at one temperature. When the gas-solid combinations are heated the gas becomes greatly pressurized and is released from the solid. The high pressure gas is precooled and then expanded through the J-T valve.

For example, low pressure hydrogen is absorbed into $LaNi_5$ at about room temperature. When heated to 100 C the hydrogen is pressurized from 1 atm to 40 atm and then vented. After being precooled with liquid oxygen at 70K (to drop hydrogen below its Joule-Thomson inversion temperature) the high pressure hydrogen is expanded to 0.10 atm to produce 14K temperatures. Various gas-solid mixtures can produce various low temperatures. The Jet Propulsion Lab presented a coupled series of these devices to produce liquid helium at 4.2K. Thousands of operating hours have been achieved on these types of systems without the oil contamination problems of conventional compressors and with only long life check valves as moving parts.

HIGH TEMPERATURE SUPERCONDUCTIVITY

The new high temperature, oxide superconductors were a topic of great interest at this conference. Many new ideas on the theories behind the materials, how to manufacture the ceramics, and how to turn them into useful devices were presented (often very informally with posters). The conference had been originally arranged before announcement of these materials. As a result, large sections of the presentations dealt with

the older low temperature superconducting technology. The interest in the new materials increased the attendance at the conference. Sessions on these topics became so popular that they had to be moved to larger facilities. A large number of poster papers were inserted into the existing poster sessions on the older type of superconductors.

The discussions dealt with two systems:

- the $(La_{1-x}M_x)_2CuO_{4-y}$ systems where typically

  M = Sr superconducting at 40K

- the $RBa_2Cu_3O_{7-y}$ system where typically

  R = Y superconducting at 95K

In the second system (typically called the 1-2-3 superconductor), all of the rare earths have been substituted into the ceramics. Only Ce, Pr and Tb do not show superconductivity. At this conference, and even now, the highest well-confirmed transition temperature was for $YBa_2Cu_3O_{6.95}$ at 95K.

Invited papers on high temperature oxide superconductors were given by R. B. van Dover of AT&T Bell Laboratories, M. K. Wu of the University of Alabama, and M. B. Maple of the University of California, San Diego. Dr. van Dover of AT&T suggested some standards for comparing materials. These included a narrow transition of approximately 0.3K and the observation of a nearly ideal Meissner effect. Dr. Maple's plenary session on these superconductors was a good review of the short history of the work. He showed a fascinating video of various shaped superconducting magnets sitting suspended in the air above a permanent magnet in a dish of liquid nitrogen in the laboratory--a very effective way of showing the real difference these high temperatures make. Dr. C. W. Paul Chu was listed as an invited speaker but he did not appear.

A great deal of discussion was held on the theory of these new materials as well as their crystal structure. The crystal position of the oxygen atoms appears to be crucial to the superconducting nature of the materials.

These materials are polycrystalline ceramics. Many of the problems with them stem from the presence of non-high temperature superconducting materials at grain boundaries. In the production of these ceramics, fine, intimately mixed powders of the precursors is considered important. Solution precipitation of these materials from an organic base was suggested as a potential method of doing this. Polycrystalline films of approximately 1500 A thickness have been made by dropping a gel of Ba, Y, and Cu onto a spinning substrate. Sputtering and low temperature plasma oxidation were also discussed as potential methods of production that avoided the high temperature calcination and slow cooling used to produce the materials.

Various groups presented methods of making wire from these materials. Most of them involved the manufacture of the polycrystalline superconducting material, placing it in silver tubes and then drawing them out into wire.

There was a lot of discussion of future uses for these materials. There are, however, worries about the hurdles such brittle ceramic materials must pass before becoming industrially useful. This was really brought home by the contrast between the work on these materials and the maturing technology of the older superconductors. Large commercial size spools of superconducting wire manufactured from the older technology materials were on display from a number of companies.

The keynote speaker at the awards luncheon was John K. Hulm, Research Director of Westinghouse Electric Corporation. He spoke of the development of the new high temperature superconductors and their industrial future. Moving from 4K to 95K changes the cooling requirement of a superconducting magnet system. Liquid nitrogen is much easier to handle and store. It is certainly cheaper than liquid helium. However, this is not a massive change. Cooling costs are not always the limiting feature. For example, the superconducting magnet used in the Research Division's NMR spectrometer, although cooled by liquid helium, only requires a refill every 9 to 10 months. This amounts to a cost of approximately $1200/year.

CONCLUSION

This was a useful and interesting conference. The work on cryogenic refrigeration, superinsulation and temperature measurement is directly related to work in progress in the Science Section. We are currently designing a distillation system which includes much of the technology discussed and displayed at this conference. The excitement of the new high temperature superconductors is still present at these meetings and contributes to a feeling of being on the forefront of research.

Approved:

A.F. Baljet
Manager
Electrical Research Department

Submitted:

J.R. Robins
Physical Chemist
Science Section
Electrical Research Department

APPENDIX I

Future Meetings on Cryogenics and Superconductivity

1. Discussion Meeting on High-T_c Superconductors
   Austrian Physical Society
   Austria
   February 7 - 11, 1988

2. Materials Research Society/ICMC International Meeting on Advanced Materials, Symposium on Advanced Superconductors
   Materials Research Society
   Tokyo, Japan
   May 30 - June 3, 1988

3. Cryogenic Material/Structure Applications and Properties
   Institute of Metal Research
   Shenyang, People's Republic of China
   June 7 - 10, 1988

4. ICEC12 - Twelfth International Cryogenic Engineering Conference
   University of Southhampton
   England
   July 12 - 15, 1988

5. Applied Superconductivity Conference
   San Franciso, California
   August 21 - 25, 1988

6. CEC/ICMC 1989
   University of California, Los Angeles
   June 24 - 28, 1989

APPENDIX II

Preprints From the Conference

1. Sorption Cryogenic Refrigeration - Status and Future
2. 4K Gifford McMahon/Joule-Thomson Cycle Refrigerators
3. Multilayer Insulation with Aluminized Dimpled Polyester Film
4. Theory and Technique for Reducing the Effect of Cracks in Multilayer Insulation from Room Temperature to 77 K.
5. Crack Covering Patch Technique to Reduce the Heat Flux from 77K to 4.2K Through Multilayer Insulation.
6. Systematic Analysis of Characteristics for Different Types of Multilayer Insulation.
7. Test of Multilayer Insulations for the use in the Superconducting Proton-Ring HERA.
8. System for Ultra High Vacuum made of Aluminum Alloys.
9. Thermal Performance of Candidate SSC Magnet Thermal Insulation Systems..
10. Evidence for Two Superconducting Components in Oxygen-Annealed Single-Phase Y-Ba-Cu-O..
11. High Temperature Superconductivity in the Y-Ba-Cu Oxide System.
12. Magnetization Studies of the High T_c Compound $YBa_2Cu_3O_8$..
13. Powder Preparation and Thermal Properties of 1-2-3 Y Ba Cu Oxide Superconductor..
14. Transport Critical Current in Bulk Sintered $YBa_2Cu_3O_x$ and Possibilities for Its Enhancement..
15. Point-contact Characteristics Obtained with Single-Crystal Y-Ba-Cu-O Superconductors.
16. Theory of the Orthorhombic-Tetragonal Phase Transition in $YBa_2Cu_3O_{7-x}$..

APPENDIX II (Cont'd)

17. The Potential Impact of Developing High T_c Superconductors on Superconductive Magnetic Energy Storage (SMES).

18. Evidence for Anisotropy Limitations on the Transport Critical-Current In Polycrystalline $YBa_2Cu_3O_x$.

19. Transport Critical Current in Bulk Sintered $YBa_2Cu_3O_x$ and Possibilities for its Enhancement.

20. On a Superconducting Sub-Structure in Sintered $YBa_2Cu_3O_x$ Plates.

21. Estimate of Attainable Critical Current Density in Superconducting $YBa_2Cu_3O_x$..

22. Study of Superconducting Oxides at Westinghouse.

23. Anomalous Behaviour of Tunneling Contacts in Superconducting Peroskite Structures.

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